Capability Improvements: Polarized Photoinjector*

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Operations Review
Jefferson Lab
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*** represents ~ half of total procurement budget for Capability Improvements. Other improvements described by A. Hutton (beam energy), C. Reece (srf).**

JLab Has Tough Beam Requirements

- Simultaneous CW beam delivery to three Users over vast dynamic range; e.g., 140 μA to Hall A and only 50 pA to Hall B.
- High polarization requires that we use strained layer photocathodes with low quantum efficiency (QE). We need high power lasers for high current experiments.
- “Parity-quality” beam (i.e., beam with very small helicity correlated beam asymmetries, suitable for parity violation experiments).
- Today’s success becomes tomorrow’s norm.
- Our achievements at JLab (both NP machine and FEL) have made it possible for people to discuss the possibility of building completely new machines (ERL’s, e-RHIC, EIC’s).

Source Group Achievements

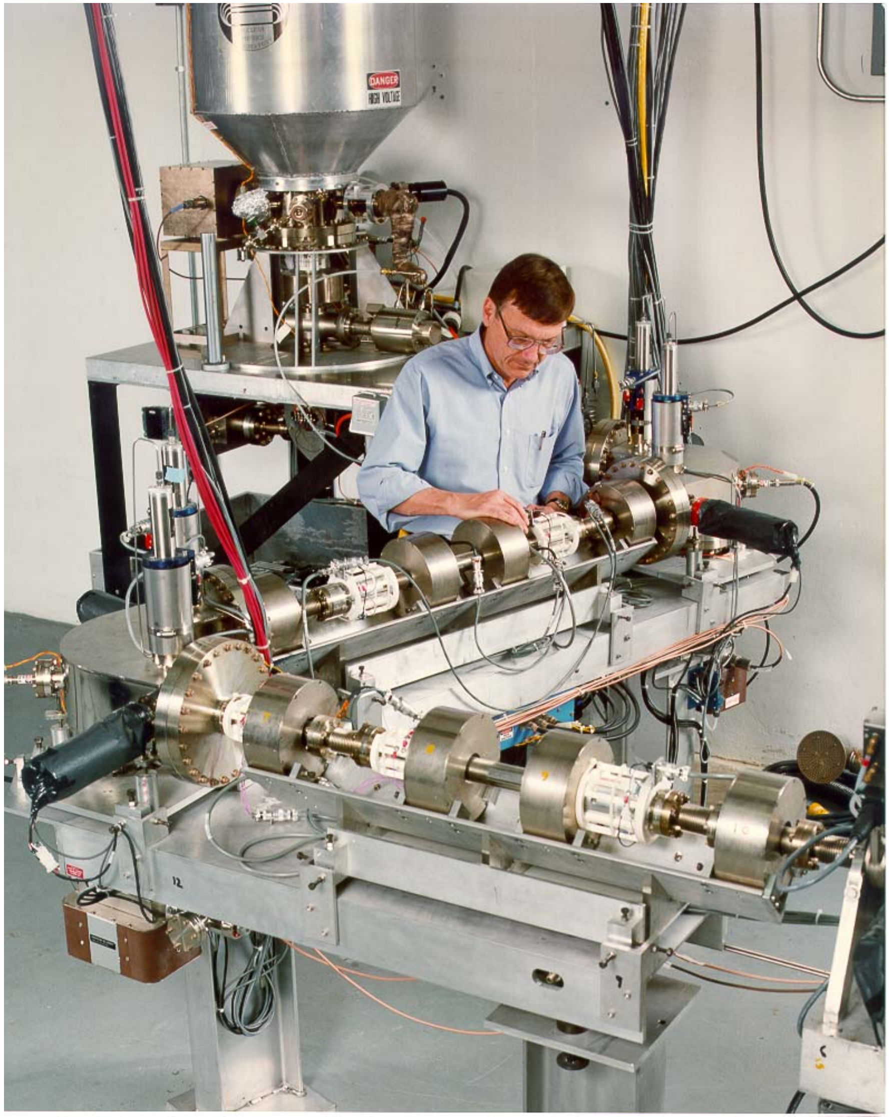
- We provide the highest available CW beam current at high polarization (>70%).
- Our guns have the longest photocathode lifetimes in the business, delivering high current beam for weeks without interruption.
- First to identify and eliminate a QE decay mechanism that had profound impact on photocathode lifetime at high current (“extra” electrons from cathode edge hit vacuum chamber walls, degrading gun vacuum).
- First parity violation experiment with strained layer GaAs.

Source Group Achievements (cont.)

- Extremely accurate Mott polarimetry at 5 MeV.
- Cross comparison of 5 polarimeters + novel spin-based absolute energy measurement.
- First to demonstrate synchronous photoinjection with new laser systems that have been copied at other other accelerators.
- Hydrogen-cleaning of photocathodes for high QE. Technology developed at JLab and transferred to other facilities.

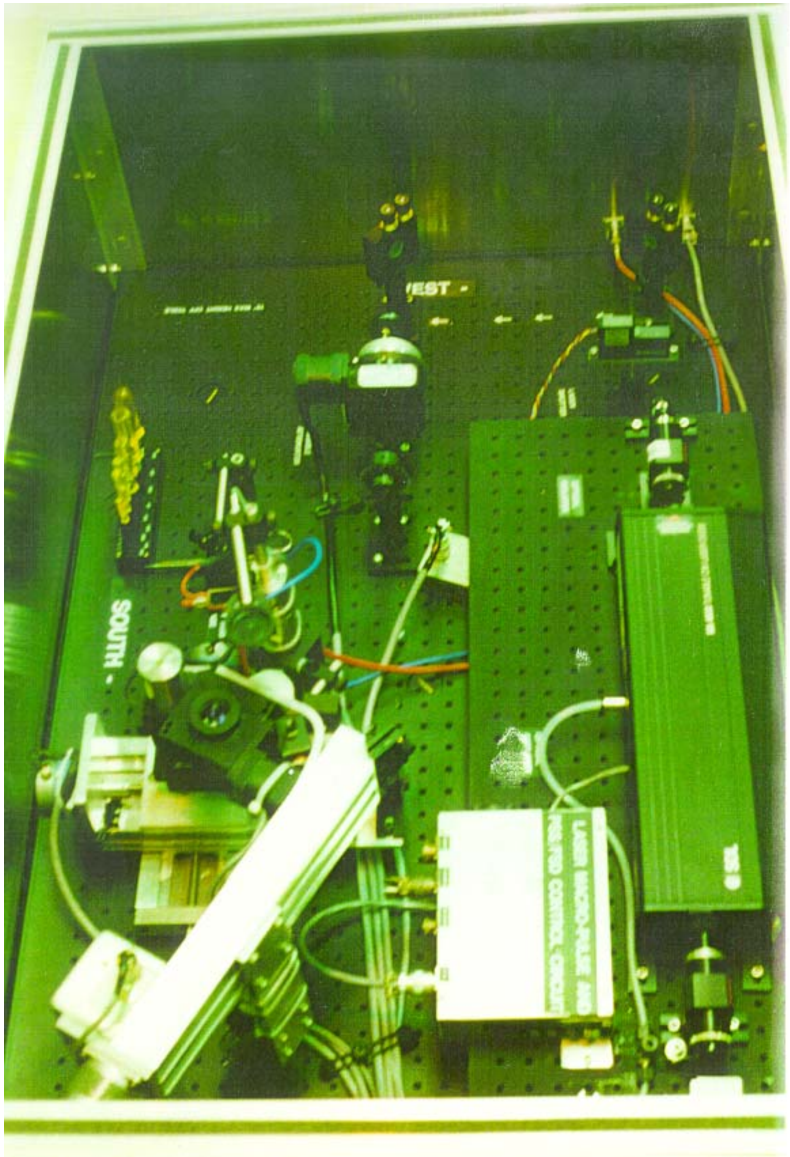
Capability Improvements: Source Group

- Feb. 1995. First beam from simple gun with Z-style spin manipulator.
- Apr. 1996. First demonstration of synchronous photoinjection. Diode laser at 1497 MHz repetition rate.
- Feb. 1997. Production beam delivery to halls (broken thermionic gun).
- Jul. 1997. Hall A first to use polarized beam for physics. 30 μA at 35% polarization.
- Dec. 1998. Feasibility study for HAPPEX (parity violation experiment).



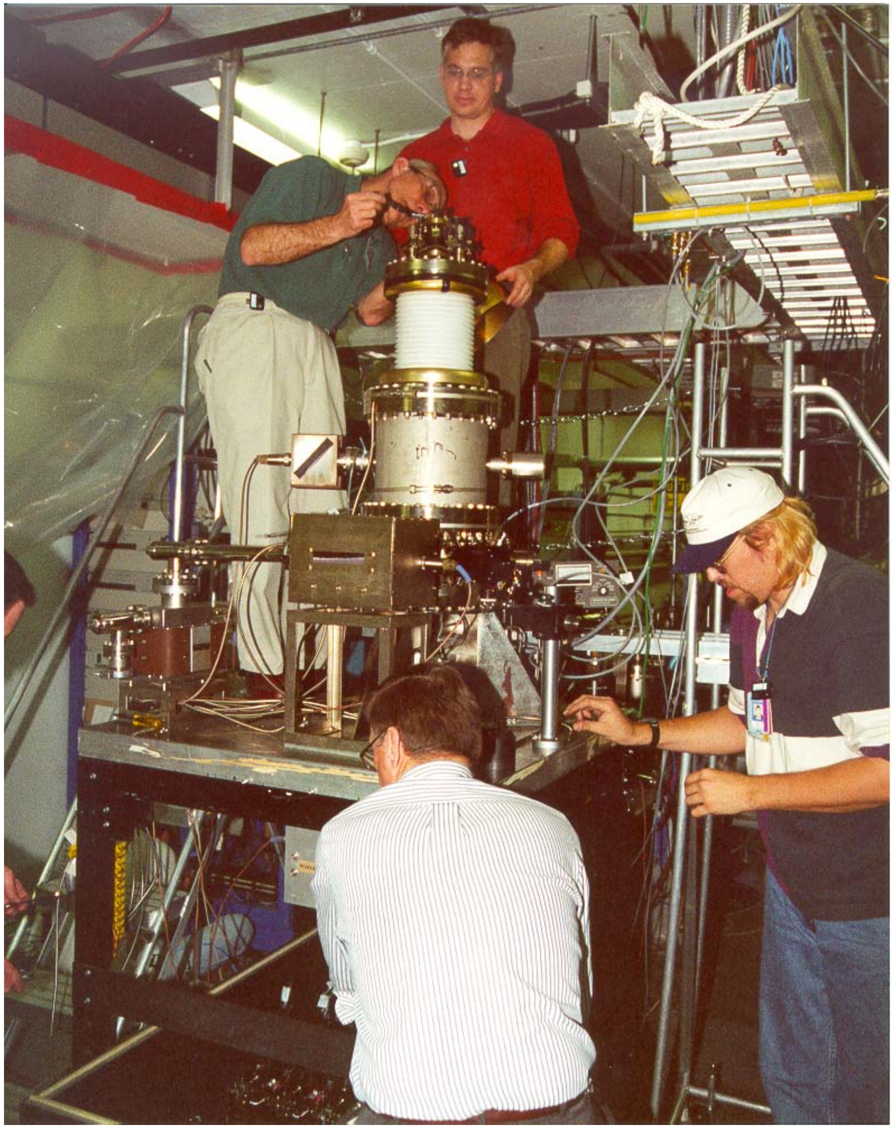
Capability Improvements: Source Group (cont.)

- Gain-switched diode laser and diode optical amplifier; combination of old and and new technology.
- Pulsed light at GHz repetition rates.
- Extremely reliable, low maintenance.
- Technology transferred to MAMI, Nagoya.



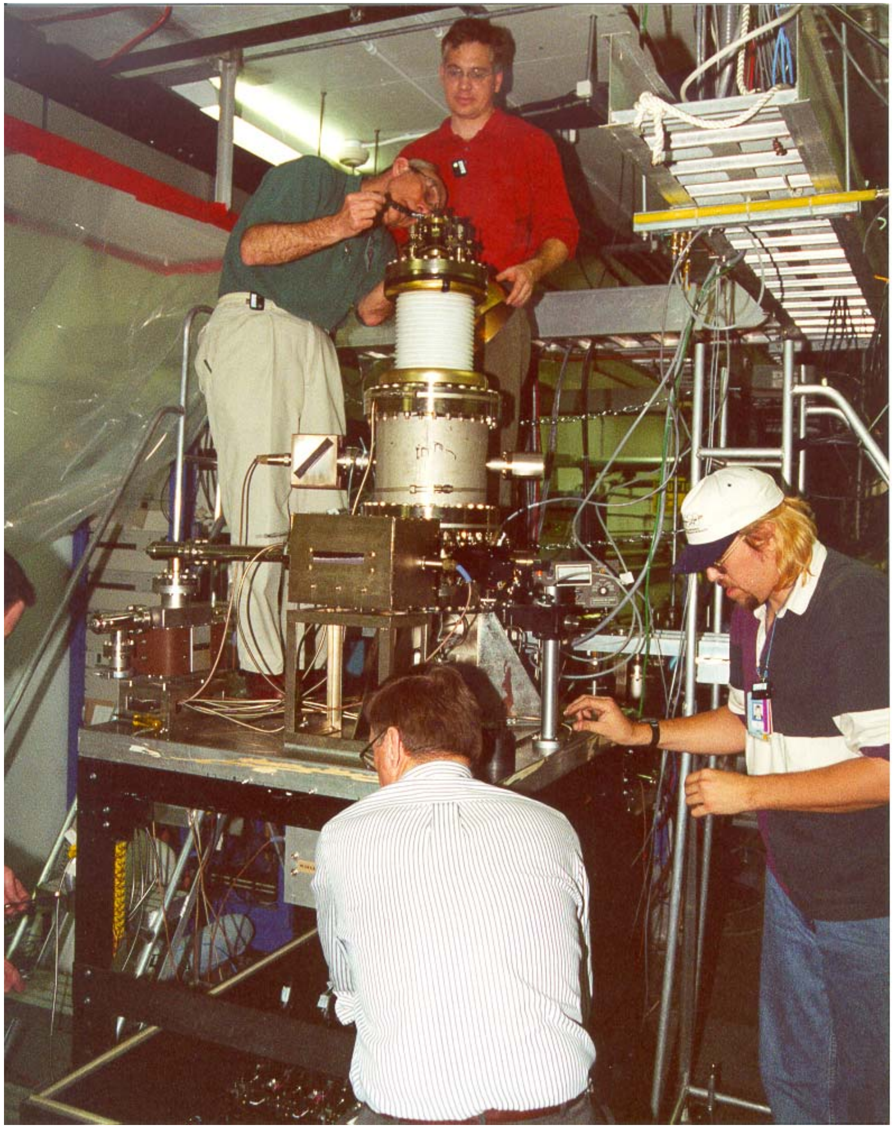
Capability Improvements: Source Group (cont.)

- Feb. 1998. Install Vertical "NEG" Gun (non-evaporable getter pumps). 4000 L/s pumping near photocathode.
- Anodize the edge of the photocathode to eliminate stray electrons, improve lifetime. Tech-transfer to MAMI.
- Replace "Z" with Wien-style spin manipulator.
- Three diode lasers at 499 MHz., one for each hall.

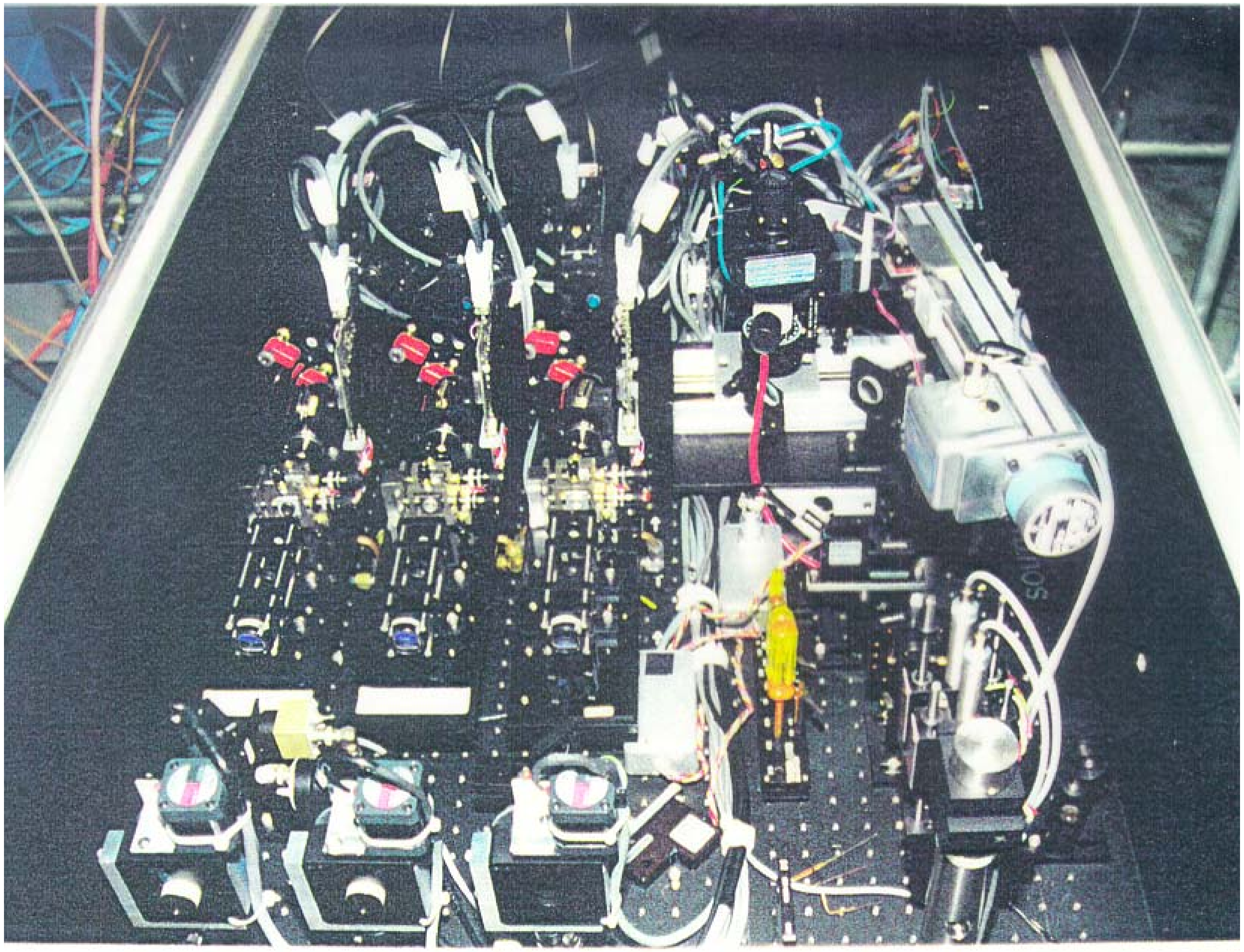


Capability Improvements: Source Group (cont.)

- Spring 1998. HAPPEX parity violation experiment with bulk GaAs. 100 μA beam with 35% polarization.
- Aug. 1998. Strained layer GaAs provides high polarization.
- Spring 1999. HAPPEX with high polarization (50 μA with 70% polarization). First to demonstrate parity-quality beam with strained layer GaAs. Integrated HC-charge asymmetry < 1 ppm.



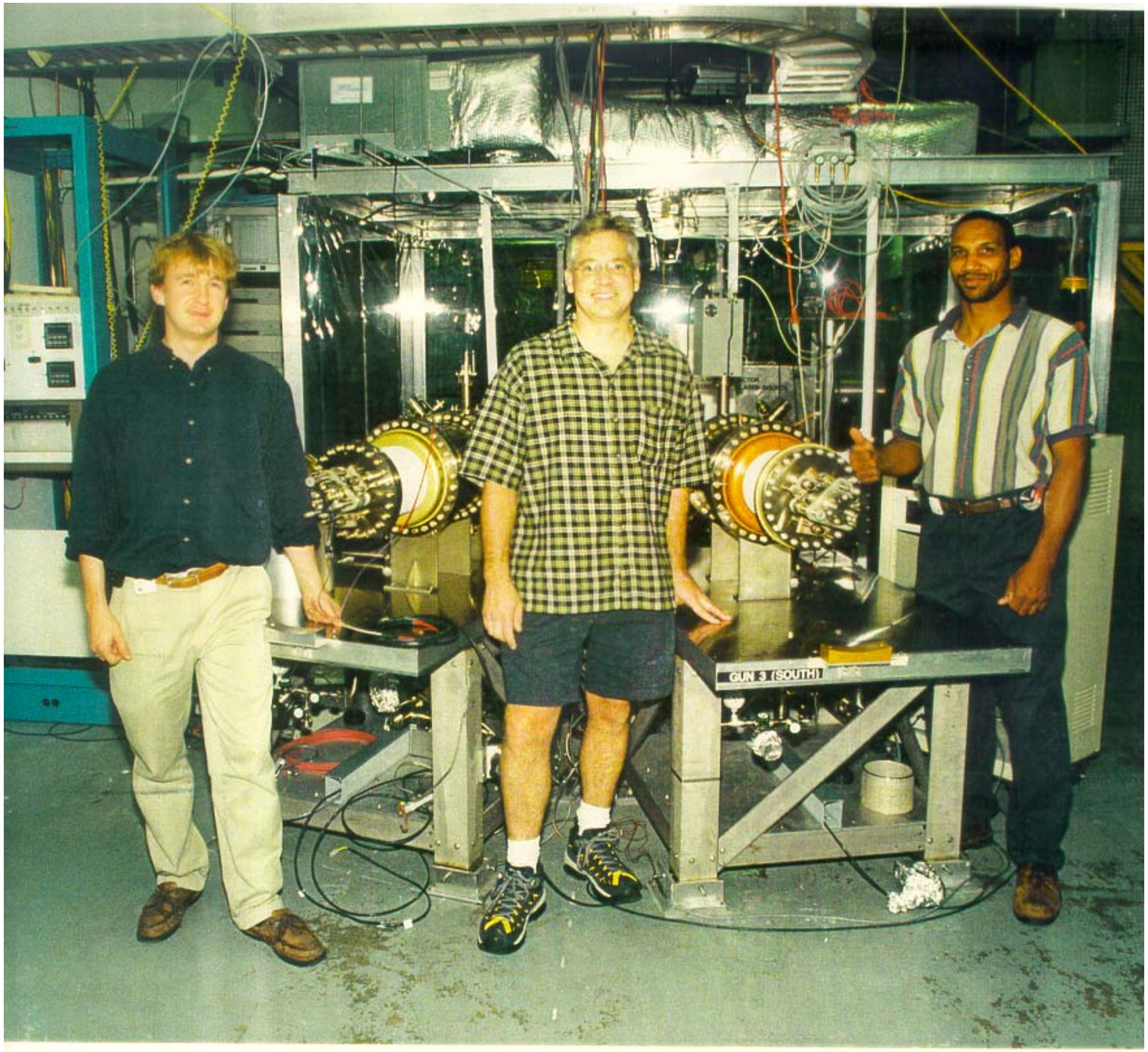
Capability Improvements: Source Group (cont.)



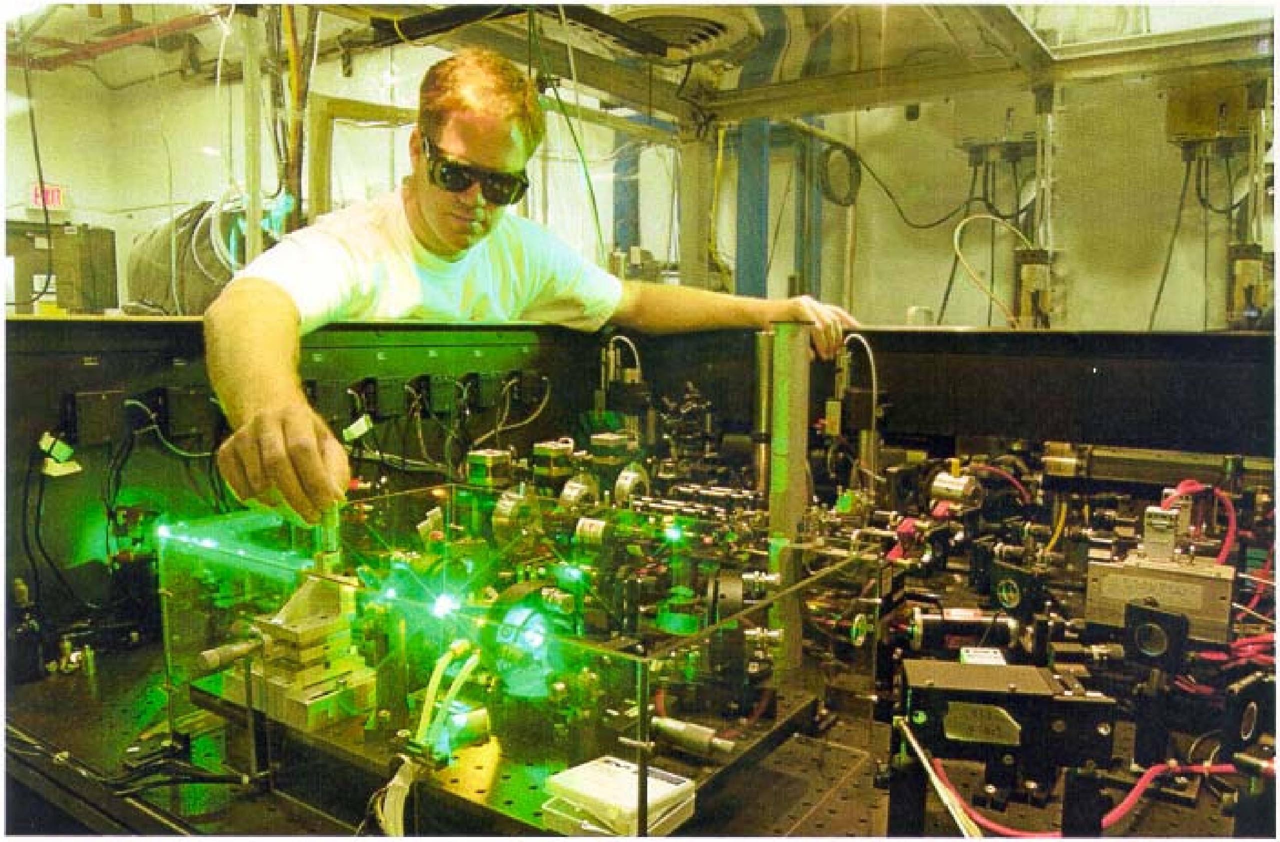
3 Diode Lasers at 499 MHz (1998), one for each hall.

Capability Improvements: Source Group (cont.)

- July 1999. Two horizontal NEG guns
- no short focal length bend magnets.
- NEG-coated beamline for more pumping, less electron stimulated desorption (first to apply CERN technology).
- Spare gun improves machine availability
- Temperature controlled laser hut.

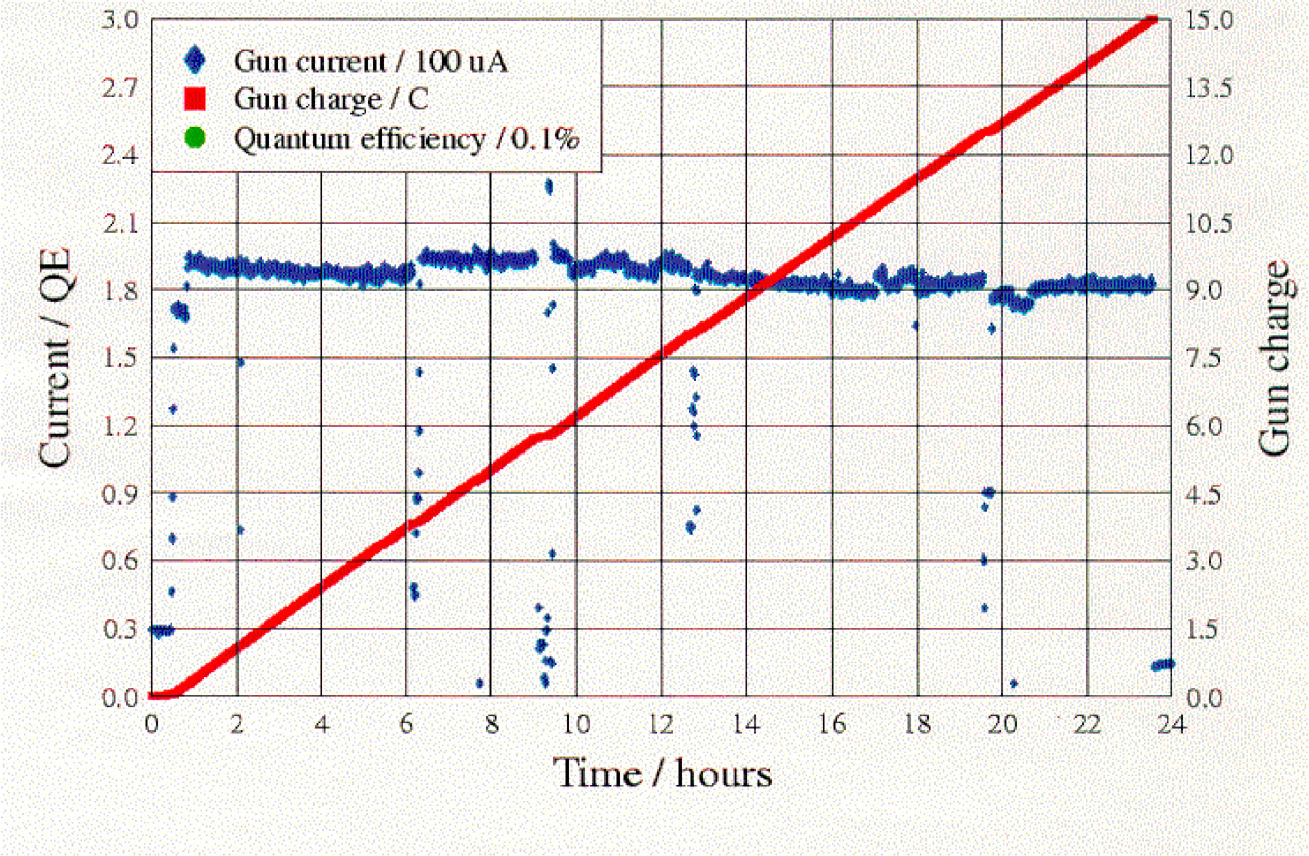


Capability Improvements: Source Group (cont.)



Nov. 2000 Modelocked Ti-Sapphire Laser for high current experiments. Novel active-modelocking technique to obtain high power and GHz repetition rates.

Capability Improvements: Source Group (cont.)



- Lifetime at high current ~ 300 Coulombs. Routine, uninterrupted beam delivery for 3 weeks.
- Lifetime at low current ~ 600 Coulombs. We recently delivered beam to 3 halls for 3 months with only one cathode activation!

Capability Improvements: Source Group (cont.)

- Electron Sources - One of JLab's Core Competencies.
- Procurement Budget $440K and 8 FTE's (4 scientists, 4 technical staff). All nuclear physics.
- Source Group formed ~ 1993 under Charles Sinclair. It grew to 12 full time members by 1998 (8 scientists, 4 technical staff) with procurement budget $1.5M.
- Present procurement budget adequate.
- We are short staffed; we need two more scientists.
  - One planned for hire in constant effort scenario.
  - One additional hire under enhanced budget request.

Mission Statement: Source Group

- We are the custodians (i.e., System Owners) of the Polarized Photoinjector, helping to ensure that JLab meets the beam requirements of its Users;
  - high current (> 100 microA per hall)
  - high polarization (> 70%)
  - Uninterrupted beam delivery (i.e., long gun lifetime)
  - Small helicity correlated beam asymmetries

Mission Statement: Source Group (cont.)

- We provide 24 hour on-call support; gun maintenance, Injector Operations, trouble shooting, etc.
- We develop new hardware to accommodate a dynamic nuclear physics program (e.g., new lasers for high current experiments or “specialty” experiments like G0).
- We study photocathode phenomena to address lifetime limitations, beam polarization, helicity correlated beam properties, etc.
- More and more, we must respond to requests for more stringent beam requirements to help Users conduct more demanding experiments (e.g., parity violation experiments).

Skills Base: Source Group

To meet our goals we maintain a broad field of expertise;

- ultrahigh vacuum technology
- mechanical skills
- electronics design and fabrication
- photocathode preparation, activation and evaluation
- polarimetry
- laser technology

Present Group Members

Group Member	Title	Experience (yrs)
Poelker, Matt	Staff Scientist	10
Adderley, Phil	Vacuum Specialist	10+
Hansknecht, John	Electronics/Laser Technician	10+
Clark, Jim	Mechanical/Vacuum Technician	10+
Day, Tony	Electronics Technician	7
Grames, Joe	Staff Scientist	2
Baylac, Maud	Staff Scientist	1
Stutzman, Marcy	Staff Scientist	1

Past Group Members (cont.)

Past Group Members	Title	Experience (yrs)
Sinclair, Charlie	Sr. Staff Scientist	25+
Schneider, Bill	Sr. Mechanical Engineer	25+
Kazimi, Reza	Staff Scientist	10
Price, Scott	Staff Scientist	10
Dunham, Bruce	Staff Scientist	10
Kehne, Dave	Staff Scientist	10
Steigerwald, Michael	Staff Scientist	7
Hartmann, Peter	Staff Scientist	7

R&D to Accommodate Physics Program

- Laser Research and Development
- Reduce/Eliminate Helicity Correlated Asymmetries in beam properties; intensity < few ppm, position < few nanometers, energy
- Deliver Higher Beam Polarization, > 80%
- High current, high polarization 2mA DC Gun for the Nuclear Physics Machine.

Laser Research and Development

- All high current, high polarization experiments demand that we improve and reinstall the modelocked Ti-Sapphire laser. Goal; stable, maintenance-free 2 Watt laser (compared with 100 mW diode laser systems).

- Construct and install modelocked Ti-Sapphire laser for the G0 experiment (high bunch charge beam with 31 MHz pulse repetition rate compared to nominal 499 MHz JLab beam).

Reduce/Eliminate Helicity Correlated Beam Asymmetries

- Parity violation experiments demand that we minimize the helicity correlated beam asymmetries that originate at the photocathode; beam current variation < 1 ppm, position variation < 20 nm. We work closely with User groups to do this.

- Study causes of helicity correlated beam asymmetries in laboratory and on machine.

- Develop feedback mechanisms to minimize helicity correlated beam asymmetries.

Increase Beam Polarization > 80%

- Figure of Merit = P^2 *I. Higher beam polarization would allow some Users to conduct their experiments more quickly. Less beam time per experiment improves JLab's productivity.
- Continue laboratory studies; new material, new procedures.
- Find additional sources of photocathode material. Collaborate with University Research groups that have photocathode fabrication capabilities.

High Current Gun Research

- Explore lifetime limitations of the present gun (3 weeks uninterrupted beam delivery at high current, 3 months at low current).
- Improve Gun Lifetime:
  - more pumping, better pumping of trouble gas species
  - better vacuum chamber material
  - improved designs to reduce sensitivity to ion backbombardment
- Commission the JLab load-locked gun.
- 2 mA DC gun with high polarization for nuclear physics photoinjector.

2 mA DC Gun for Nuclear Physics Photoinjector

- Our lasers do not turn completely OFF between pulses. As a result, each laser gives a little beam to the other halls. The result - Polarization Dilution. Low current Users suffer the most.
- DC gun gives Users better beam; no polarization dilution.
- A simple Injector (fewer rf settings to worry about).
- Seemed impossible in 1995 when we developed rf-pulsed lasers. Photocathode lifetime would be too short at 2 mA.
- Potentially useful for future accelerator projects like ERL's, e-RHIC, EIC, etc.

Stumbling Blocks Associated with Flat or Reduced Funding

- Short staffing makes it difficult to meet objectives in timely manner.
- Group has suffered attrition. Only three veteran group members remain from our heyday (one scientist, two technicians). New members need training which is time consuming.
- Further attrition? The group must retain core knowledge base. A worst case scenario: JLab loses the diverse skills associated with keeping a photogun working.

Stumbling Blocks Associated with Flat or Reduced Funding (cont.)

- Beam time is oversubscribed. No machine time devoted to commissioning new equipment. Our betaware gets commissioned in a production environment, a frustration to Source Group members and Users alike.

Reasons for Attrition

- Photogun Scientists acquire highly marketable skills. Better pay in industry.
- Scientists frustrated with 24 hour on-call support. Difficult to find time for research.
- All research is User-driven (i.e., the research must have a direct application to the immediate nuclear physics program). No opportunity for "pure" research.

Summary

- Source Group has always functioned lean compared with other labs (e.g., SLAC). We are *really* lean now.
- We've done some great work and we will continue to do great work in the future.
- Adding one more scientist Spring 2002 and continued training of young scientific staff will go a long way toward helping us meet our near-term goals. Reduces burden of 24 hour on-call support. Increases opportunities for R&D. Our constant effort scenario; 9 group members (5 scientists, 4 tech staff).
- Adding another scientist will help us meet our long term goals. 10 group members (6 scientists, 4 tech staff). JLab program less sensitive to attrition. Our enhanced budget scenario.

Summary (cont.)

- Our achievements with photoguns at JLab (including FEL) have made it possible for us to consider accelerator projects that seemed outlandish 6 years ago. (high current, high polarization DC gun for NP machine and photoguns for ERL's, e-RHIC, EIC projects).
- Imagine saying;
  - "routine" parity violation experiments with HC charge asymmetry control better than 1 ppm
  - "routine" 85% beam polarization
  - "trouble-free" operation of 2 mA, high polarization photogun.

Capability Improvements: Source Group

History of JLab Polarized Photoinjector:

- Feb. 1995 First beam from JLab polarized gun (simple gun with Z-style spin manipulator and DC HeNe laser).
- Apr. 1996 Synchronous photoinjection at 1497 MHz. Diode laser system.
- Feb. 1997 Thermionic gun breaks. Begin using the polarized gun for production beam delivery to halls.
- Jul. 1997 Hall A first to use polarized beam for physics, ~ 30 microA and 35% polarization.
- Dec. 1997 Feasibility study for HAPPEX (parity violation experiment)
- Feb. 1998 Vertical "NEG" gun (non-evaporable getter pumps) with Wien-style spin manipulator. Three diode laser systems, one for each hall.

Capability Improvements: Source Group (cont.)

History of JLab Polarized Photoinjector (continued)

- Spr. 1998 HAPPEX with bulk GaAs photocathode. 100 microA beam at 35% polarization.
- Aug. 1998 Strained layer GaAs photocathode provides high beam polarization.
- Spr. 1999 HAPPEX with strained layer GaAs photocathode. 50 microA at 70% polarization.
- Jul. 1999 Two horizontal "NEG" guns.
- Nov. 2000 Used high power modelocked Ti-Sapphire laser to deliver high current and high polarization to two halls simultaneously (GEn and GEp).
- Sum. 2001 Delivered beam to three halls for three months with only one cathode activation. 1/e lifetime ~ 600 Coulombs!